

Electromagnetic sounding of Mars from a lander or rover: Results of an instrument study for 2007.

Tom G Farr¹, DW Beaty¹, P Gogineni², J Grant³, R Grimm⁴, C Leuschen², GR Olhoeft⁵, A Safaeinili¹, ¹Jet Propulsion Laboratory, California Institute of Technology, tom.farr@jpl.nasa.gov, ²University of Kansas, ³National Air and Space Museum, ⁴Blackhawk Geoservices, Inc., ⁵Colorado School of Mines.

A Study Team was chartered to assess the feasibility of electromagnetic sounding from a Mars lander or rover, possibly in 2007. We considered both high- and low-frequency systems. Energy transport at high frequency is propagative (wave-like) and is controlled by the electrical permittivity and the magnetic permeability. This is the Ground Penetrating Radar (GPR) regime. At low frequencies, energy transport is by diffusion and is controlled by the magnetic permeability and the electrical conductivity. This is the inductive regime. The division between the two formally occurs where the loss tangent (the ratio of the energy loss to energy storage) is unity; for typical terrestrial near-surface electromagnetic properties, the transition is at ~10 MHz. Therefore terrestrial GPRs operate between about 10-1000 MHz, and inductive measurements are made from <<1 Hz to >100 kHz.

Advantages of radar include relatively low mass and power, high signal controllability, and high resolution imaging of subsurface cross sections. The principal disadvantages are potentially strong losses due to absorption and scattering, limiting penetration depth to a few hundred meters, material contrasts that are relatively small, high accuracy position and orientation requirements, and high data rates. Inductive methods have much greater penetration depth (several km), higher sensitivity to the geoelectric section and simpler operation and interpretation, but have lower resolution overall. In addition, low-frequency transmitters generally require greater mass and power than radar, and methods that use natural sources are subject to the existence, location, and timing of natural sources.

Electromagnetic sounding from a Mars lander or rover will provide unique information about subsurface conditions and geology, including the possibility of detecting water. A GPR operating in two frequency bands centered around 10 MHz and 500-1000 MHz or sweeping through the 10-1000 MHz region, would provide information about the subsurface perhaps down to several 100 m, with high resolution at shallower depths. This technique is considered essential for targeting a mobile drill and for providing 3-dimensional geologic context for drill results. Without a GPR, we will be drilling "blind". GPR could also be used for subsurface hazard avoidance (e.g. dust-bridged desiccation cracks) during long rover traverses.

Low-frequency EM techniques could operate in either a passive or active mode. A passive EM sounder would

rely on natural electromagnetic sources such as diurnal changes in Mars' ionosphere and could sound to many km depth. Active low-frequency sounders require relatively large antennas and significant power, but have advantages from the ability to control the source location, geometry, orientation and frequency. Due to the depth of penetration and high sensitivity, low-frequency inductive techniques have the best chance of detecting liquid water. A GPR and passive low-frequency sounder are therefore strongly recommended; an active low-frequency sounder also may be recommended, depending on mission and resources.

Part of this work was performed under contract to NASA